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11. SUPPLEMENTARY NOTES

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13. ABSTRACT *(Maximum 200 words)*
Major improvements have been made in the fabrication and in the performance characteristics of boron carbide-based, wide-band gap semiconductor devices. During this grant, working boron carbide transistors, tunnel junctions and homojunction diodes were fabricated. These transistors and diodes were the first carbide based devices of their type to be reported in either academic laboratories or in industry. Protocols for boron carbide substrate fabrication were optimized and the boron carbide thin films were deposited on a wide variety of substrates, including Si(111), aluminum, steel, gold, titanium and silver. PACVD (photoassisted chemical vapor depostion) methods using orthocarborane as a source molecule, were tailored to achieve band gaps of up to 4.0 eV with temperature stability to 250 C. The boron carbide material was successfully doped both n-type and p-type, and methods of tuning the band gap by inclusion of phosphorus-containg dimeric chloro-phospha-3-carborane allowed the band gap to be tuned reliably over the range of 0.7 to 2.4 eV by appropriate adjustment of feed gas. A novel class of CVD molecules, the metallocenes, were used for n-type doping. The sensitivity of these molecules to electron or photon beams have also allowed metal wires and other metal-metal containing features to be written with dimensions as small as 500 angstroms in resolution.

14. SUBJECT TERMS
Boron carbide, metallocene, orthocarborane, ferrocene, nickelocene, manganocene, wide band gap materials, photolithography

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I. INTRODUCTION

This final technical report summarizes progress made in AFOSR grant # F49620-94-1-0433, entitled "Photoassisted Chemical Vapor Deposition for Packaging and Fabrication of Wide-Band Gap Semiconducting Devices". The grant provided $313,070 in funding over the period 9/1/94 to 8/31/97 and involved collaborative efforts in physics, chemistry and engineering disciplines. In addition to the three co-investigators (Profs. Peter Dowben , Marjorie Langell and Natale Ianno), two postdoctoral researchers, seven graduate students and seven undergraduate students were associated with the project, resulting in 21 publications, two patents, 18 presentations and four theses. Collaborative efforts were established and/or expedited with Leybold-Inficon (Syracuse, NY), IBM (Dr. Datta, Endicott, NY), the Naval Research Laboratory (F.K. Perkins, Electronic Materials Division), Litton (Dr. Cole, Wright Laboratories), Oak Ridge National Laboratories (Drs. W. Plummer and J. Zhang), Salford University (Dr. Boag, Salford University, U.K.), University of Idaho (Dr. D. McIlroy) and Rome Laboratories (Dr. P. Carr).

The goal of the project, as described in the original research proposal, was to make major improvements in fabrication and performance characteristics of wide band gap semiconductor devices with specific focus on achieving an actual, working boron carbide-based device. Focus was placed on developing boron carbide-based homojunction and heterojunction prototype devices through *p*hotoassisted *c*hemical *v*apor *d*eposition (PACVD) methods. The aim was not to make marginal improvement in current device properties but to develope truly novel materials for use in high power, high voltage applications under extreme temperature conditions. Results from this project include as highlights:

- diode fabrication on a wide variety of substrates, including titanium and steel
- tailoring of PACVD methods to achieve band gaps of up to 4.0 eV with temperature stability to 250 °C
- successful n and p type doping of boron carbide
- fabrication of the first working boron carbide tunnel junction device
- extension of working devices to homojunction and heterojunction devices
- development of CVD methods for attaching wires with dimensions down to 500 Å

All goals of the project have been met or exceeded. Details are given below.

II. RESEARCH ACCOMPLISHMENTS

II.A. PACVD Fabrication of Thin Film $B_{1-x}C_x$

The synthesis of boron carbide substrates suitable for wide band gap device usage had been an elusive goal in the improvement of extreme-condition semiconductor devices. Previous attempts to fabricate boron carbide thin films either deposited the less useful cubic form or resulted in films with properties so poor as to be useless for device purposes. The rationale for

the present approach was to employ CVD precursor molecules, taken from the carborane family, that already had the desirable icosahedral framework. The most successful carborane employed in this project is orthocarborane, shown in figure 1. Our previous success with this substrate [1] formed a basis for the AFOSR proposal.

By this method, boron carbide has been successfully deposited on a number of substrates, including Si(111), polycrystalline aluminum, gold, titanium and silver. The material is not purely crystalline, but does maintain a high degree of the original carborane structural integrity [2]. For example, the field effect transistor shown in figure 2, was fabricated to produce a B/B_5C heterojunction with quite acceptable I-V characteristics [3]. The B_5C film is almost entirely icosahedral, with less than 1% of the boron carbide found in other structural forms. Carborane-deposited B_5C is very insensitive to crystallite size and its device-quality deposition appears to be generally applicable to all common substrates.

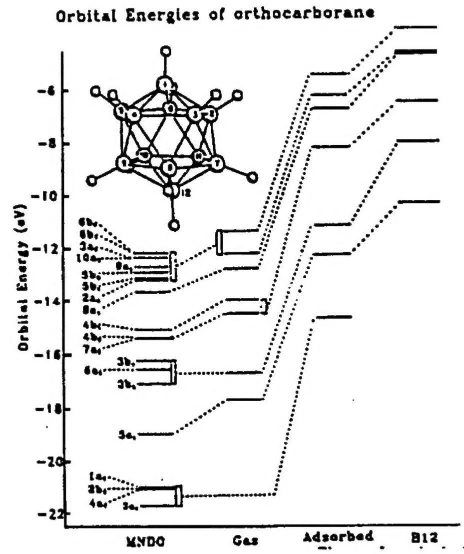

Figure One. Orthocarborane and its energy levels. Atoms 1, 2 are carbon. Unnumbered atoms are hydrogen. The remainder (3-12) are boron.

II.B. Synchrotron and X-ray Assisted Diode Fabrication

Under the terms of this grant, protocols were developed for depositing $B_{1-x}C_x$ materials using photolithographic CVD conditions (PACVD), during which the carborane framework remained largely intact. This procedure had the added benefit of high spatial control of deposition in a single-step process. Carborane fragmentation in this photolithographic process was studied in detail [4] and PACVD was found compatible with high resolution (submicron) device fabrication [5]. In addition to demonstrating the feasibility of single-step PACVD for boron carbide deposition, our consortium has optimized the fabrication methods for maximum performance of B_5C thin film substrates.

II.C. B_5C Dopants

A crucial step in implementing boron carbide PACVD as a synthetic method for device fabrication is the development of suitable routes to doping the thin films. Both p-type and n-type boron carbides have been prepared, characterized and used successfully in prototype devices. The introduction of phosphorus into the boron carbide lattice was effected with dimeric chloro-phospha-3-carborane, a caged molecule in which two phosphorus atoms bridge a set of orthocarborane units. However, this did not result in the expected p-type doping found with silicon and other semiconductor substrates, perhaps because the molecular structure remains too similar to the parent CVD molecule in which phosphorus is only three-coordinant. Interestingly, inclusion of less than 1% phosphorus in the PACVD process widens the band gap of the boron carbide thin film with a maximum value to date of 4.2 eV. This phosphorus compound has also allowed the band gap to be tuned reliably and reproducibly over the range of 0.7 to 2.4 eV by appropriate adjustment of CVD feed gas pressures [6,7]. Other source molecules were also

explored for the introduction of phosphorus [8,9].

Fortunately, B_5C made from photo-assisted CVD of orthocarborane, itself, is weakly p-type. As a result, the majority of efforts to dope boron carbide films has been directed towards developing n-type doping protocols. The classic dopant, mercury, is not compatible with carborane PACVD, since it cannot be incorporated into the boron carbide lattice but precipitates to produce inhomogenous mercury deposits in the carbide film [10].

Instead, a novel class of CVD precursor molecules, the metallocenes, were developed for

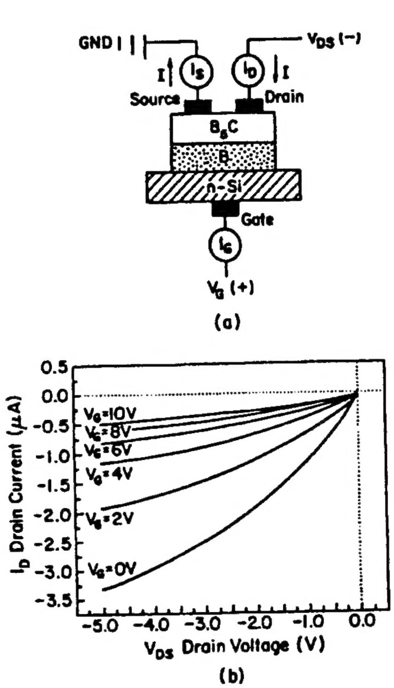

Figure Two. I-V data for a B/B_5C heterojunction field effect transistor.

this purpose [11,12]. Since metallocenes have the added benefit of being photon or electron beam activated for metal deposition, they have also be used to prepare nano-dimensioned wires, contacts and other metallic features [13]. Ferrocene, $Fe(C_5H_5)_2$, and nickelocene, $Ni(C_5H_5)_2$, are n-type dopants. Surprisingly, maganocene, $Mn(C_5H_5)_2$, acts as a p-type dopant. While the mechanism for p-type defect formation is not yet understood, identification of a useable dopant adds flexibility to the use of B_5C as a p-type semiconductor [7,11,12].

II.D. Prototype B_5C Devices

Due to the high quality of boron carbide that can be produced by the orthocarborane PACVD method, actual devices can now be fabricated with boron carbide substrate materials. The first working boron carbide-based device ever to be demonstrated, a silicon-B_5C diode, was reported in 1995 by members of this research consortium under sponsorship of the present AFOSR grant. Boron-boron carbide heterojunctions quickly followed. Upon establishment of appropriate dopant methods, homojunction devices and tunnel diodes were also made feasible and demonstrated as actual prototype devices. These devices have all been characterized electrically (I-V curves, conductivity measurements, etc.) and have been shown to perform at or above current industrial standards. As examples,

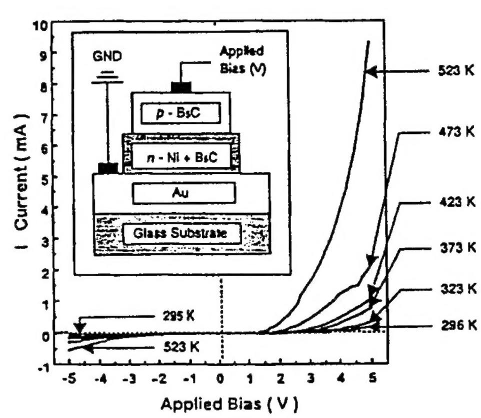

Figure Three. Boron carbide homojunction diode I-V characteristics as a function of temperature.

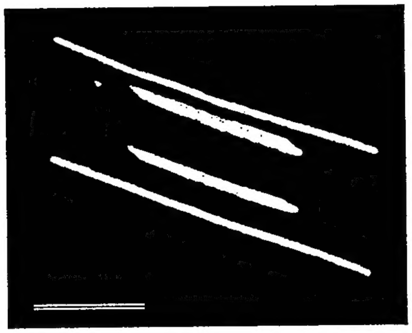

Figure Four. Microdimensioned iron wires fabricated by e-beam assisted CVD, viewed by TEM. The scale is given by the separation between parallel bars in the lower left, which represents 0.5 µm.

figures 2 and 3 show I-V curves for a B/B_5C heterojunction field effect transistor and a boron carbide homojunction transistor, respectively. Heterojunction devices can be made operational to 250 °C (523 K), as shown in figure 3. At 298 K, conductivities as low as 10^{-10} $(\text{Ohm-cm})^{-1}$ can be routinely obtained. The material has been thoroughly characterized by electronic and optical techniques, and the role of excess hydrogen has been investigated.

Goals of making the devices increasingly smaller have capitalized upon the remarkably clean decomposition available with the metallocene CVD precursor molecules. Dimensions of wires, connections and dopant areas using metallocenes are limited by the electron or photon source used to initiate decompositon [13,14]. Several nanoscaled features of single-step CVD writing of metallized features are shown in figure 4.

II.E. Wires

In addition nanoscaled features resulting in the electron and photon decomposition of metallocenes (*e.g.* Ni, ref. 13), we have electrolytically deposited wires of palladium with dimensions as small as 500 Å across using STM techniques[14]. Similar techniques have also been developed for copper [15]. Presently, we are working on protocols for fabricating very thin LaB_6 wires. Initial attempts have made low-dielectric LaB_6 wires that are microns long, but are only a few hundred angstroms wide. These electrode materials are envisioned as potential electron ejection sources for micron-sized solid state devices.

II.F. Summary

All goals of AFOSR project #F49620-94-1-0443 have been met or exceeded. Significant accomplishments include demonstration and optimization of PACVD growth of thin film boron carbide substrates, development of dopant and metallization protocols compatible with this wide bandgap material and demonstration of actual, working prototype devices. Most significant are the fabrication and characterization of the first working boron carbide transistor, tunnel junction and homojunction diodes to be reported by either commercial or academic laboratories. The boron carbide substrate has superior temperature stability, wide band gap characteristics and optical characteristics that make it clearly suitable for high-quality, high-performance device applications. Miniaturization of wires, contacts and other metallized device features has also been possible with single-step electron or photon assisted CVD utilizing metallocene precursor molecules.

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III. Personel Associated with AFOSR #F49620-94-1-0433

Two postdoctoral research associates, Dr. David N. McIlroy and Dr. Charles Hutchings, were asssociated with this project. Dr. McIlroy has accepted a tenure track assistant professorship in physics at the University of Idaho and, at the time of this report, he is in his second year of this position. Seven graduate students, Dong Byun, Dullip Welipitiya, Seong-Don Huang, Amad A. Ahmad, Gregorgy Carson, David Pugmire and Cynthia Woodbridge also contributed to the project. Three of them, Byun, Welipitiya and Carson, received their Ph.D. degrees under sponsorship or partial sponsorship of this grant. Their work is included in section **II. Research Accomplishments**. Drs. Byun and Welipitiya are employed in industry; Dr. Carson has taken a faculty position at Chadron State College in Chadron, NE. Seven undergraduates, Nick Rennes (UNL), Arthur Cunningham (REU, Notre Dame), R. Clint Johnson (REU, Colorado College), Ken Yang (REU Washington State U.), Melanie Jagannathan (REU, U. Iowa), Gaetan Couderc (Besancon, France) and Lawrance Sage (Besancon, France), were an integral part of the program. REU, Research Experience for Undergraduates, is an NSF-sponsored program that pays stipends and modest travel expenses for undergraduate students to conduct 10-12 weeks of summer research with UNL faculty in on-going research problems. AFOSR sponsored graduate/postdoctoral supervision of these students, provided equipment and supplied operating expenses for contributions to the research described above.

IV. Publications under AFOSR #F49620-94-1-0433

1. D. Byun, S.D. Hwang, P.A. Dowben, F.K. Perkins, F. Filips and N.J. Ianno, "Heterojunction Fabrication by Selective Area Chemical Vapor Deposition Induced by Synchrotron Radiation", *Appl. Phys. Lett.* **64**, 1968 (1994).
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21. Ahmad A. Amad, N.J. Ianno, Seong-Don Hwang and P.A. Dowben, "Sputter Deposition of High Resistivity Boron Carbide", submitted.

V. Patents under AFOSR #F49620-94-1-0433

1. P.A. Dowben, "Forming B1-xCx Semiconductor Devices by Chemical Vapor Deposition" US Patent #5468978 Nov. 21, 1995.
2. P.A. Dowben, "Boron-Carbide and Boron Rich Rhombohedral Based Transistors and Tunnel Diodes", US Patent applied for 1997.

VI. Presentations under AFOSR #F49620-94-1-0433 (* indicates invited talk)

1.* "The Importance of Physics Research to Industry", Crete Rotary Club, Crete, NE, June 1, 1994 [presented by P.A. Dowben].

2.* "High Resolution Electron Energy Loss Spectroscopy of Metal Oxides", American Physical Society, March Meeting, San Jose, California, 1995 [presented by M.A. Langell].

3. "Synchrotron Radiation Induced Decomposition of closo-1,2-dicarbadodecaborane" , 41st National Symposium of the American Vacuum Society, Octber 26, 1994, Denver, CO, paper EM-ThP24, Dongjin Byun, Seong-don Hwang, Jiandi Zhang, Hong Zeng, F. Keith Perkins, G. Vidali and P.A. Dowben [presented by Dongjin Byun].

4. "An STM Study of Molecular Intermediates in the Dissociative Adsorption of closo-1,2-dicarbadodecaborane on Si(111)", 41st National Symposium of the American Vacuum Society, Octber 26, 1994, Denver, CO, paper NS-TuP16, J.M. Carpinelli, E.W. Plummer, D. Byun and P.A. Dowben [presented by P.A. Dowben].

5. "Comparison of Different Source Compounds for the Fabrication of Heterojunction Boron Carbide Diodes", 1994 Fall MRS Meeting, Boston Massachusetts, November 30, 1994, paper E8.28, Dongjin Byun, B.R. Spady,N.J. Ianno and P.A. Dowben [presented by Dongjin Byun].

6. "Fabrication of Boron Carbide Transistors on Si(111) from Closo-1,2-dicarbadodecaborane and nido-decaborane", 1994 Fall MRS Meeting, Boston Massachusetts, December 1, 1994, paper F27.2, Dongjin Byun,and P.A. Dowben [presented by Dongjin Byun].

7.* "Cluster Molecule Adsorption: A Route to Making New Materials", Materials Science Seminar, University of Wisconsin, Madison, Wisconsin, December 1, 1994 [presented by P.A. Dowben].

8.* "Cluster Molecule Adsorption: A Route to Making New Materials", Solid State Division Seminar, Oak Ridge National Laboratory, Oak Ridge, January 5, 1995 [presented by P.A. Dowben].

9. "Cluster Molecule Adsorption: A Route to Making New Materials", IUVSTA Workshop on: The Structure and Reactivity of Small Molecules on Surfaces, Brdo, Solvenia, April 15th, 1995 [presented by P.A. Dowben].

10.* "Cluster Molecule Adsorption: A Route to Making New Materials", Fachbereich Chemie, Freien Berlin, Berlin, FRG, April 18th, 1995 [presented by P.A. Dowben].

11. "Fabrication and Characateriaztion of Micron Scale Features", ARPA/NRL/ONR Magetic Materials and Devices Workshop, May 17, 1995 [presented by P.A. Dowben].

12. "The Characteristics of Ni doped B5C/Si Heterojunction Diodes Fabricated by Plasma Enhanced Chemical Vopr Deposition (PECVD)", Rocky Mountain Chapter of the AVS, 1995 Annual Symposium, Aug. 24, 1995, Arvaada, Colorado [presented by Seong-don Hwang].

13. Ferrocene Adsorption of Ag(100)", Rocky Mountain Chapter of the AVS, 1995 Annual Symposium, Aug. 24, 1995, Arvaada, Colorado [presented by Dulip Welipitiya].

14. "Ferrocene Adsorption on Ag(100)", 42nd National Symposium of the AVS, Oct. 17, 1995, Minneapolis, MN, Paper ss-TuP28, D. Welipitiya, J. Zhang, J.P. Woods and P.A. Dowben [presented by Dulip Welipitiya].

16.* "Band Gaps of Doped and Undoped Films of Molecular Icosahedra", International Conference on Nano-Clusters and Granular Materials (NCGM'95), Sendai, Japan, Sept. 21, 1995 [presented by D.N. McIlroy].

17. "Ferrocene Adsorption on Ag(100)", 30th Midwest Regional Meeting of the ACS, Nov. 2, 1995, Joplin, MO, Paper 93D, D. Welipitiya, J. Zhang, J.P. Woods and P.A. Dowben [presented by Dulip Welipitiya].

18. "A Study of the Dopant Driven Transition of an Insulating Film of Molecular Icosahedra into a Semimetallic Phase", paper A7-1, March Meeting of the American Physical Society, St. Louis, Mo., March 18, 1996, [presented by D.N. McIlroy] published Abstract: D.N. McIlroy, C. Waldfried, P.A. Dowben and D. Heskett, Bull. Am. Phys. Soc. 41 (1996).

19. "Nickel Doping of Boron Carbide and Fermi Level Shifts", 3rd International High Temperature Electronics Conference, Albuquerque, New Mexico, June 12, 1996, published abstract: Peter Dowben, Seong-Don Hwang and D.N. McIlroy, "Nickel Doping of Boron Carbide and Fermi Level Shifts", Transactions Volume 1of the 3rd International High Temperature Electronics Conference, pg XII-3 to XII-8.

20. "Nickel Doping of Boron Carbide and Fermi Level Shifts", Rocky Mountain Chapter of the American Vacuum Society, 1996, Annual Symposium, Arvada, CO, Aug. 22, 1996 [presented by Seong-don Hwang].

21. "Sputter Deposition of High Resistivity Boron Carbides", 43rd Annual AVS Meeting, Philadelphia, PA, Oct. 1996 [presented by Natale J. Ianno].

22. "Nickel Doping of Boron Carbide and Corresponding Fermi Level Shifts", 43rd National Symposium of the American Vacuum Society, Philadephia, Pennsylvania, Oct. 15, 1996 [presented by David McIlroy], paper EM-TuP18, D.N. McIlroy, S.D. Hwang, N. Remmes and P.A. Dowben.

23.. "The Effects of Doping on the Transport and Device Characteristics of Boron-Carbon Alloy Materials", paper C12-7, March Meeting of the American Physical Society, Kansas City, Missouri, March 17, 1997, [presented by D.N. McIlroy], published abstract: D.N. McIlroy, J.Z. Li, J.Y. Lin, H.X. Jiang, N. Remmes, Ken Yang, S.-D. Hwang and P.A. Dowben, Bull. Am. Phys. Soc. 42 (1997) 125.

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A. Biographical Summary:

Personal Data: Born July 24, 1955 in San Antonio, Texas

Educational Background:
1977 B.A. in mathematics and physics, Haverford College, Haverford, PA.
1981 Ph.D. in physics, Cavendish Laboratory, Univesity of Cambridge, England

Honors and Awards:
St. John's College Benefactors Studentship, 1978 P 1980
I.U.V.S.T.A. Welch Scholarship, 1981 P 1982
SigmaPXi Outstanding Faculty Research Award, 1989
Univ. of Nebraska, College of Engineering Multidiscplinary Research Award, 1997

Professional Experience:
1995 - present: Professor of Physics and Graduate Fellow, University of Nebraska
1994 - present: Research Professor of Chemistry, University of Nebraska
1993 - 1995: Associate Prof. of Physics and Graduate Fellow, University of Nebraska
1990 - 1994: Associate Prof. of Physics, Syracuse University, Syracuse, New York
1987 - present: Adjunct Prof. of Chemistry, Syracuse University
1986 - 1993: Member of Solid State Science and Technology Program, Syracuse University
1984 - 1990: Assistant Prof. of Physics, Syracuse University
1981- 1983: Scientist with the FritzPHaber Institut der MaxP PlanckPGesellschaft FRG,
1981: Visiting Scientist to the Departent of Physics, University Osnabruck, FRG
1980 P 1981: Research Assistant to Dr. M. Grunze, FritzPHaber Institut der MaxPPlanck Gesellschaft, and the Dept. of Physical Chemistry, Free University, Berlin, FRG

B. Research:

Interests and Capabilities
The electronic structure of organometallic and main group cluster molecules. Investigating electronic phase transitions in reduced dimensionality. Specific techniques include anglePresolved photoemission and resonant photoemission as well as inverse photoemission and spin polarized inverse photoemission. Other techniques include spin polarized photoemission, LEED, thermal desorption spectroscopy and characteristic energy loss spectroscopies.

Publication Record
Author of more than 190 articles in refereed journals and books, 9 invited review articles, 5 invited presentations at national and international conferences, and 4 patents.

Three Related Publications:
"Determining the Bonding Orientation of Molecular Adsorbates on Metal Surfaces by Angle Resolved Photoemission", P.A. Dowben, (invited review), Z. Phys. Chem. (1997), in press
"The Nonmetal to Metal Transition with Alkali Doping of Films of Molecular Icosahedra", D.N. McIlroy, C. Waldfried, T. McAvoy, Jaewu Choi, P.A. Dowben and D. Heskett, Chem. Phys. Lett. 264 (1997) 168-173
"Fabrication of Boron Carbide - Boron Heterojunction Devices", Seong-Don Hwang, Dongjin Byun, N.J. Ianno, P.A. Dowben and H.R. Kim, Appl. Phys. Lett. 68 (1996) 1495-1497
Graduate advisors: Prof. David Tabor, Dr. R.G. Jones and Dr. Lionel Clarke
Post-doctoral Advisor: Prof. Michael Grunze

C.V. Marjorie A. Langell

A. Bibliographic Summary

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Educational Background:

1979, Ph.D., 1976 M.A., in Chemistry, Princeton University, Thesis: Surface Characterization of the Cubic Sodium Tungsten Bronze (100) and Tungsten Trioxide (100) Single Crystals; 1974, B.S., in Chemistry, University of Connecticut, Thesis: Synthesis of 5-exo-methyl-2-norbornene.

Professional Experience

September 1994-present	Professor of Chemistry University of Nebraska, Lincoln, NE 68588-0304
August 1987-July 1994	Associate Professor of Chemistry University of Nebraska, Lincoln, NE 68588-0304
August 1981-July 1987	Assistant Professor of Chemistry University of Nebraska, Lincoln, NE 68588-0304
September 1979-June 1981	Postdoctoral Research Associate Department of Chemistry, University of California, Berkeley, CA 94720
September 1980-November 1980	Instructor Department of Chemistry, Mills College, Oakland, CA 94613

B. Five Relevant Publications

1. M.A. Langell, C.L. Berrie, M.H. Nassir and K.W. Wulser, "Adsorption of Acetic Acid on Hydroxylated NiO(111) Thin Films", *Surface Sci.* **320** (1994) 25.
2. M.A. Langell and M.H. Nassir, "Stabilization of NiO(111) Thin Films by Surface Hydroxyls", *J. Phys. Chem.*, **99** (1995) 4162.
3. G. Carson, M.H. Nassir and M. A. Langell, "Epitaxial Growth of Co_3O_4 on CoO(100)", *J. Vac. Sci. Technol.*, **A14** (1996) 1637.
4. M.A. Langell, C.W. Hutchings, G.A. Carson and M.H. Nassir, "High Resolution Electron Energy Loss Spectroscopy of MnO(100) and Oxidized MnO (100)", *J. Vac. Sci. Technol.*, **A14** (1996) 1656.
5. J.L. Armstrong, J.M. White and M.A. Langell, "Thermal Decomposition Reactions of Acetaldehyde and Acetone on Si(100)", *J. Vac. Soc. Technol.*, **A15** (1997) 1146.

C.V. Natale J. Ianno

A. Bibliographic Summary

Present Position: Professor of Electrical Engineering, University of Nebraska-Lincoln

Address:

Center for Materials Research and Analysis and Department of Electrical Engineering, University of Nebraska, Lincoln, Nebraska 68588-0511. Tel: (402) 472-1965, E-Mail: Nianno@Unlinfo.Unl.Edu.

Educational Background:

1981, Ph.D., 1980, M.S., B.S. 1978, in Electrical Engineering, The University of Illinois-Urbana.

Field of Specialization:

Electron cyclotron resonance (ECR) etching of semiconductors, in-situ process monitoring and control, plasma deposition, sputter deposition.

B. Publications

Summary:
Prof. Ianno has over 30 refereed journal publications, 50 conference presentations and has had greater than $1,000,000 in external grants and contracts.

Five Relevant Publications:

1. D.N. McIlroy, S.D. Hwang, K. Yang, N. Remmes, P.A. Dowben, A.A. Ahmad and N.J. Ianno, "The Incorporation of Nickel and Phosphorus Dopants into Boron-Carbon Alloy Thin Films",J. Phys. C, **320** *in press.*
2. S.D. Hwang. K. Yang, P.A. Dowben, A.A. Ahmad, N.J. Ianno, J.Z. Li, J.Y. Lin, H.X. Jiang and D.N McIlroy, "Fabrication of n-type Nickel Doped $B_5C_{1+\delta}$ Homojunction and Heterojunction Diodes", *Appl. Phys. Lett.*, **70** (1997) 1028.
3. A.A. Ahmad, N.J. Ianno and P.G. Snyder, "Optical Properties of Boron Carbide B_5C Thin Films Fabricated by Plasma Enhanced Chemical Deposition", *J.Appl. Phys.*, **79** (1996) 1.
4. D. Byun, B.R. Spady, N.J. Ianno and P.A. Dowben, "Comparison of Different Chemical Vapor Deposition Methodologies for the Fabrication of Heterojunction Boron-Carbide Diodes" *Nanostructured Mater.*, **5** (1996) 465.
5. P.G. Snyder, N.J. Ianno and B. Wigert, "Spectroscopic Ellipsometric Monitoring of Electron Cyclotron Resonance Etching of GaAs and AlGaAs", *J. Vac. Soc. Technol.*, **B13** (1995) 2255.